

# Interfacing a Differential-Output (Isolated) Amplifier to a Single-Ended Input ADC



## Introduction

Whether you are sensing current in an industrial 3-phase servo motor system, a battery management system for an electric vehicle, or a photo voltaic inverter, it is often necessary to include some sort of safety isolation scheme. Safety-related standards define the specific isolation requirements for the end equipment associated with the particular design. Various factors come into play when determining what level of safety insulation (basic, supplemental, or reinforced) is required depending on the type of equipment, the voltage levels involved, and the environment that the equipment is to be installed.

Texas Instruments offers a variety of isolated current shunt amplifiers that are used in the previously-mentioned applications for voltage and current shunt sensing that meet either basic or reinforced insulation requirements. For applications requiring reinforced insulation, one such device is the AMC1301. The output of the AMC1301 is a fully differential signal centered around a common-mode voltage of 1.44 V that can be fed directly to a stand-alone analog-to-digital converter (ADC) as shown in Figure 1, or to the on-board ADC found in the MSP430 and C2000 family of micro-controller devices.

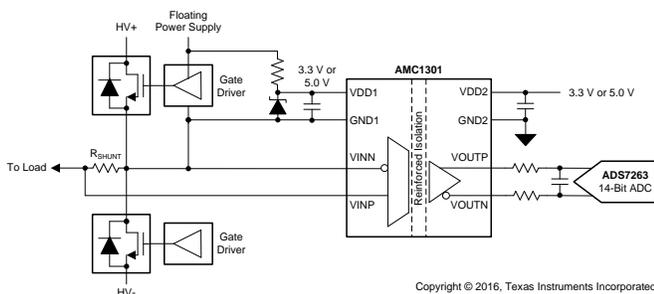


Figure 1. AMC1301 Functional Block Diagram

## Embedded ADCs

Both the MSP430 and C2000 family of processors have embedded single-ended input ADCs so the question becomes, “How do I get this differential signal into my single-ended data converter?”

The simplest way to achieve this is to use only one output of the AMC1301 leaving the second output floating. The down side to this solution is that only half the output voltage swing is available to the data converter, reducing the dynamic range of the

measurement. The analog input range to the AMC1301 is  $\pm 250$  mV. With a fixed gain of 8.2, the VOUTN and VOUTP voltages are  $\pm 1.025$  V centered around the 1.44-V common-mode output as shown in Figure 2. Differentially, the output voltage is  $\pm 2.05$  V.

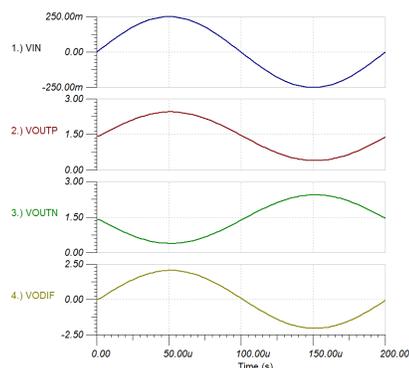


Figure 2. Differential Output Voltage

The addition of a differential to single-ended amplifier output stage, illustrated in Figure 3, allows the full output range of the AMC1301 to be provided to the ADC.

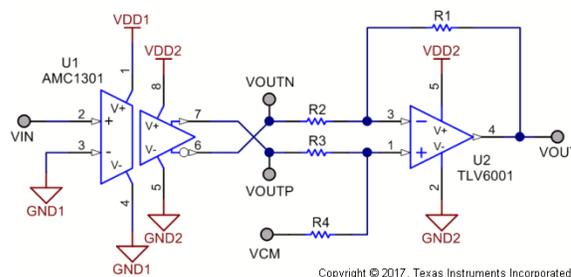


Figure 3. Differential to Single-Ended Output

Assuming a full scale sine wave of  $\pm 250$  mV is applied at VIN; the internal gain of the AMC1301 will provide 2.05 Vpk-pk outputs at points VOUTP and VOUTN which are  $180^\circ$  out of phase. The difference between these signals, VODIF, is 4.1 Vpk-pk. When  $R1 = R4$  and  $R2 = R3$  the transfer function of the output stage is shown in Equation 1.

$$VOUT = VOUTP \times \left(\frac{R4}{R3}\right) + VOUTN \times \left(\frac{R1}{R2}\right) + VCM \quad (1)$$

With equal value resistors for R1 through R4 in Equation 1 and VCM set to 2.5 V, Equation 1 reduces to:

$$V_{OUT} = (V_{OUTP} - V_{OUTN}) + V_{CM} \quad (2)$$

The plots of Figure 4 show the input voltage and output voltages of the AMC1301 along with the output voltage of the final differential to single-ended output stage. Note that the differential voltage of  $\pm 2.05$  V is transposed to a single-ended signal from 0.5 to 4.5 V.

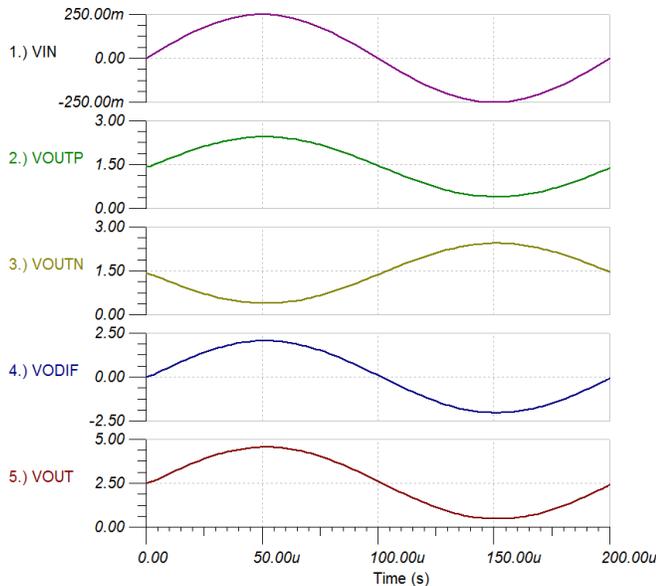


Figure 4. Single-Ended Output Voltage

Depending on the input voltage range of the ADC, gain or attenuation can be incorporated into the differential to single-ended stage to adjust the output swing. The output common mode voltage can be adjusted to fit the input needs of the ADC as well.

### Design Example

The ADC12 found on the MSP430 devices have an input voltage range of 0–2.5 V when using the internal voltage reference. Using the VOUTP from the AMC1301 would provide the ADC12 with an input signal ranging from 0.415 V to 2.465 V, well within the input range of the converter while only utilizing half the

input range of the AMC1301. As shown in Figure 5, utilizing a differential to single-ended amplifier configuration with a gain of 0.5 and common mode voltage of 1.25 V, the entire voltage range of the AMC1301 can be applied to the ADC12.

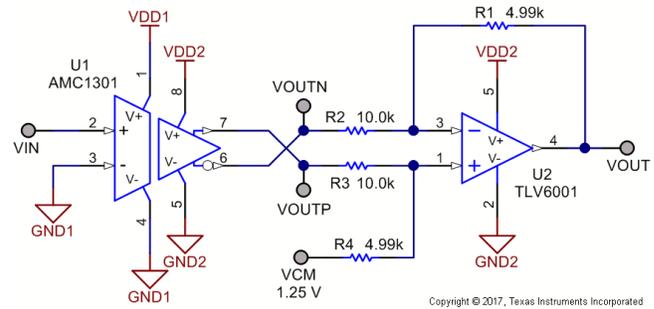


Figure 5. Scaled Differential to Single-Ended Output

### Alternative Device Recommendations

The AMC1100 or AMC1200 provide basic isolation with similar performance to the AMC1301 at a lower price point. For applications requiring a bipolar output option, the TLV170 is an excellent choice.

Table 1. Alternative Device Recommendations

Device	Optimized Parameter	Performance Trade-Off
AMC1100	Galvanic Isolation up to 4250 V <sub>PEAK</sub>	Lower Transient Immunity
AMC1200	Galvanic Isolation up to 4250 V <sub>PEAK</sub>	Basic Isolation versus Reinforced
TLV170	Bi-polar operation to $\pm 18$ V	Higher input bias current

### Conclusion

While it is possible to use a single output of the AMC1301 to drive a single-ended ADC, adding a differential to single-ended op-amp stage at the output ensures the target application will have the largest possible dynamic range.

Table 2. Related TI Tech Notes

SBOA161	Low-Drift, Low-Side Current Measurements for Three-Phase Systems
SBOA165	Precision Current Measurements on High Voltage Power Supply Rails

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